# Effect of surface conditioning with airborne-particle abrasion on the tensile strength of polymeric CAD/CAM crowns luted with self-adhesive and conventional resin cements

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Effect of surface conditioning with air-abrasion on the tensile strength of polymeric CAD/CAM crowns luted with self-adhesive and conventional resin cements


## ABSTRACT

**Statement of problem.** Adhesively bonded, industrially polymerized resins have been suggested as permanent restorative materials. It is claimed that such resins present similar mechanical properties to glass ceramic.

**Purpose.** To assess the tensile strength of polymeric crowns following different conditioning protocols; luted with self-adhesive cements to dental abutments and with conventional resin cements.

**Material and methods.** Human teeth were prepared for all crowns and divided into 13 groups (N=312, n=24 per group). Polymeric crowns were CAD/CAM fabricated, and divided into 3 groups depending on different surface conditioning methods: A) No treatment, B) airborne particle abrasion with 50 µm alumina, and C) airborne-particle abrasion with 110 µm alumina. Thereafter, the crowns were luted on dentin abutments with the following cements: 1) RXU (RelyX Unicem, self-adhesive), 2) GCM (G-Cem, self-adhesive), 3) ACG (artCem GI, conventional), and 4) VAR (Variolink II, conventional). Glass ceramic crowns milled and cemented with dual-polymerized resin cement (Variolink II) acted as the control group. The tensile strength was measured initially (n=12) and after aging by mechanical thermocycling loading (1 200 000 cycles, 49 N, 5°C to 50°C) (n=12). The tensile strength (MPa) of all crowns was determined by the pull-off test (Zwick/Roell Z010; Ulm, Germany, 1mm/min).

Subsequently, the failure types were classified. Data were analyzed with 2-way and 1-way ANOVA followed by a post hoc Scheffé test and t-test ($\alpha$=.05).

**Results.** No adhesion of the tested cements was observed on unconditioned polymeric CAD/CAM crowns and those luted with VAR. Among the tested cements, GCM showed significantly higher values after air-abrasion with 110 µm (initial: 2.8 MPa; after aging: 1 MPa) than 50 µm alumina (initial: 1.4 MPa; after aging: 0 MPa). No significant effect was found between 50 and 110 µm particle size alumina in combination with the other 2 cements. After aging, the tensile strength of the crowns luted with GCM (50 µm: 0 MPa and 110 µm: 1 MPa) and ACG (50 µm: 1 MPa and 110 µm: 1.2 MPa) was significantly lower than those luted with RXU (50 µm: 1.9 MPa and 110 µm: 2 MPa). All air-abraded polymeric CAD/CAM crowns (initial: 1.4-2.8; 0-2 MPa) showed significantly lower tensile strength values than the control group (initial: 7.3 MPa; after aging: 6.4 MPa). While with all polymeric specimens, failure type was adhesive between the cement and the crowns, the control group showed exclusively cohesive failures within the ceramic.

**Conclusion.** Air-abrasion before cementation of polymeric CAD/CAM crowns has minimally improved the tensile strength. Both the failure types and the tensile strength values of adhesively luted glass ceramic crowns showed superior results to adhesively cemented polymeric ones. Although the tensile strength results were low, crowns cemented with RXU showed, after aging, the highest tensile strength of all other tested groups.

**Clinical Implication.** The adhesion of tested polymeric CAD/CAM crowns to dentin was considerably lower than that of the glass ceramic crowns.

**INTRODUCTION**

Computer aided design and computer aided manufacturing (CAD/CAM) technology allow the production of dental restorations with numerical controlled machining. This technology has been successfully established for milling ceramic materials and other materials have recently been introduced as an economic alternative to ceramics for dental reconstructions, with lower expenditure of time and costs. One such example is polymeric CAD/CAM blocks for interim dental restorations.[1] Such materials are based on polymethylmethacrylate (PMMA), urethane dimethacrylate (UDMA), and bisphenolglycidyldimethacrylate (BisGMA) types of resins.

Since these CAD/CAM blocks are industrially polymerized under high pressure and temperature, they present superior mechanical properties to the manually polymerized resins.[1-3] In general, although the manually polymerized resins show lower fracture resistance, they are only indicated for interim fixed dental prostheses (FDPs).[1-3] Because of their good optical and mechanical properties, as well as their less abrasive effect on the antagonist enamel,[4] recently introduced polymeric CAD/CAM blocks are considered as alternative materials to glass ceramic.[5] However, limited information is available on their mechanical durability with and without aging regimens.[1,3] Alt et al[1] reported that after 3 months of water storage at 37°C and 5000 thermocycles, industrially polymerized 3-unit FDPs showed significantly higher fracture load than manually polymerized ones.

Since these materials are also indicated for long-term restorations, their adhesion is of importance for their durability. To the authors` best knowledge, at present, there is no information available on the retentive strength of polymeric CAD/CAM crowns. Adhesion of resin-based cements includes both conditioning the cementation surface of the restorations as well as the prepared dentin. One of the most common methods of conditioning polymeric materials is the use of airborne-particle abrasion, which in principle cleans the surface and at the same time increases the surface area.[6,7] Similar effects are observed in glass ceramics after hydrofluoric acid etching.[8]

Adhesion has 2 aspects, and for durable restorations not only the conditioning of the restorative material but also the dentin is crucial for adequate bonding of the resin cement to both substrates. Etching-and-rinse bonding systems are considered as the gold standard for conditioning dentin. However, because of their technique sensitivity, some of the conventional resin cement systems have involved self-etch adhesives. These self-etch adhesive cements do not require conditioning of the dentin, which eliminates technique sensitivity.[9]

The adhesion of such cements could be individually tested either on the restoration material or on the tooth substrate.[10,11] However, in order to simulate a more realistic clinical environment , investigation of the tensile strength of luting agents can be studied by using a pull-off test involving axial dislodgement forces  acting on crowns luted to extracted human teeth.[12-16]

The aim of this study was to investigate the effect of air-abrasion with 2 particle sizes of the abrasive and resin cements on the tensile strength of polymeric CAD/CAM crowns bonded to dentin. The null hypotheses tested were that polymeric and glass-ceramic crowns conditioned or non-conditioned would not show significant difference in terms of tensile strength.

## MATERIAL AND METHODS

Extracted caries-free molars (N=312) were collected, cleansed of periodontal tissue residues and stored in 0.5% Chloramine T at room temperature for 1 week. Thereafter, they were stored in distilled water at 5°C for a maximum of 6 months.[17] The roots of each tooth were embedded with acrylic resin (ScandiQuick: SCAN DIA; Hagen, Germany) in a special device held parallel to the long axis of the tooth.

The teeth were prepared with a motorized parallelometer (PFG 100: Cendres Métaux; Biel-Bienne, Switzerland) with a conicity of 10 degrees, and the shoulder preparation was made with a 40 µm diamond rotary cutting instrument (FG 305L/6: Intensiv SA; Grancia, Switzerland). To obtain a standardized coronal height of 3 mm, the holding device was positioned in a cut-off grinding machine (Accutom-50: Struers GmbH; Ballerup, Denmark). The coronal line angles were rounded with a polishing disc (Sof-Lex 1982C/1982M: 3M ESPE; Seefeld, Germany). The specimens were stored in water at 37°C before cementation and testing.

The prepared abutments were scanned with a Cerec 3D camera (Sirona; Bensheim, Germany) and the bond surface area was calculated (Cerec Software 2.80 R2400 Volume Difference: Sirona). The crowns were designed (Cerec InLab 3D Program Version 3.10: Sirona) for each abutment and milled with Cerec InLab XL (Sirona).

The 288 tooth specimens with milled polymeric CAD/CAM crowns were divided into 3 main pretreatment groups (n=96). Within main group 1, the polymeric crowns were not treated. Within main group 2, the crowns were air-abraded with alumina powder with a mean particle size of 50 µm (LEMAT NT4: Wassermann; Hamburg, Germany) for 10 s at a pressure of 0.2 MPa from a distance of 10 mm. Within main group 3, the crowns were air-abraded with alumina powder with a mean particle size of 110 µm as described for main group 2. Subsequently, the polymeric crowns of each main group were cemented according to the manufacturers` instructions under 100 N load on dentin abutments with the following resin cements (n=24 per resin cement): RelyX Unicem (RXU: 3M ESPE), G-CEM (GCM; GC Europe; Leuven, Belgium), artCem GI (ACM: Merz Dental; Lütjenburg, Germany), and Variolink II (VAR:

Ivoclar Vivadent) (Table I). The size of the specimen (n=12 per subgroup) was based on a previous study, which showed significant differences with a similar specimen size.[13] No formal power analysis was performed prior to initiation of the study. The cements were occlusal photopolymerized for 30 s (Elipar S10, 3M ESPE). Then the specimens in all groups were stored in an incubator for 10 min at 37°C and loaded in a special device with 100 N for simulating finger pressure during cementation of a crown.[18]

For the control group, conventional glass ceramic crowns (VITA Mark II: VITA Zahnfabrik; Bad Säckingen, Germany) were etched (9% buffered hydrofluoric acid: Ultradent Products; South Jordan, Utah) and treated with a silane coupling agent (Monobond S: Ivoclar Vivadent; Schaan, Liechtenstein) and an adhesive (Heliobond: Ivoclar Vivadent) according to the manufacturer's instructions. The abutment surfaces were conditioned with Syntac Classic (Ivoclar Vivadent), and crowns were cemented with resin cement (Variolink II: Ivoclar Vivadent) according to the manufacturer's instructions.

While the initial tensile strength was measured in half of each group (n=12), the other half (n=12) was subjected to mechanical thermo-mechanical cyclic loading (chewing simulator, University Zurich). The crowns were loaded under vertical compressive load with 49 N for 1.2 million times at 1.67 Hz frequency. Mesiobuccal cusps from nearly identical maxillary human molars fixed in amalgam were used as antagonists and loading points. The specimens were fixed to a holder simulating the physiologic tooth movements in the lateral direction.

Simultaneous thermocycling was achieved by changing the surrounding water temperature in the chamber every 120 s from 5°C to 50°C. In total, the temperature changed 6 000 times during the occlusal loading.[19-21] To embed the crowns in the upper holding devices and position the lower holding devices parallel maintaining a 1.5 mm space between them, the space between the lower holding devices was filled with an addition silicone (Lab Putty: Coltène/Whaledent; Altstätten, Switzerland). Acrylic resin (ScandiQuick) could be poured through the screw hole in the bottom of the holding device.

The crowns were pulled out under tensile load (Universal Testing Machine, Zwick/Roell Z010: Zwick; Ulm, Germany) at a cross head speed of 1mm/min until debonding of the crowns or facture tooth/crown took place (Fig. 1). The tensile strength of specimens that crowns separated from the debonded tooth before actual testing was considered as 0 MPa. The bond strength values were calculated (fracture load/bond area = $N/mm^2$ = MPa).

The failure types after testing were classified into 3 main groups: 1) failure at the interface of dentin and cement, 2) mixed failure, and 3) failure at the interface of polymeric crown and cement. For the failure type classification, an optical microscope at a ×25 magnification was used, and digital photos were made (Tesovar: Zeiss; Zurich, Switzerland) to collect more detailed information on the observed failure types.

The statistical analysis was made by using Statistical Package for the Social Science Version 15 (SPSS INC, Chicago, Ill). Descriptive statistics were computed. Within each pretreatment and aging group, the differences between the mean tensile strengths of different cement groups were investigated by 1-way ANOVA followed by Scheffé test. Additionally, Student's t-test was applied to investigate the influence of pretreatment for each cement type and aging group separately. P-values smaller than 5% were considered to be statistically significant in all tests. Power analysis using a two group Satterthwaite t-test with a 0.05 two-side significance level was performed with respect to the main finding of the measured tensile strength data using nQuary 6.0 (Statistical Solution, Saugus MA, USA).

**RESULTS**

The power analysis was performed for two aged groups: control group and RXU air-abraded using 110 µm alumina (Table II). A simple size of n=12 in each group will have 99% power to detect a difference in means of 4.4 given the observed deviations in both groups.

The nonconditioned polymeric crowns with all cement groups and those cemented after air-abrasion with VAR fractured before the actual tensile strength measurements under both nonaged and aged conditions. These were considered as 0 MPa (Table II, Fig. 2).

Except for the air-abraded (50 µm alumina) and aged GCM group, where all specimens were debonded after mechanical thermocycling loading, all other air-abraded groups showed significantly higher results than nontreated groups (Table IV).

The GCM group (initial and after aging) air-abraded with 110 µm alumina showed higher tensile strength results than those abraded with 50 µm alumina. Within the 50 µm alumina air-abraded groups, GCM showed the lowest initial tensile strength.

No significant differences were found with 110 µm alumina air abrasion among the initial test groups. After aging, the tensile strength of RXU was significantly higher than that of GCM.

All specimens fractured adhesively between the cements and the polymeric crowns (Fig. 3B).

The adhesively luted glass ceramic crowns (control group) showed the highest tensile strength of all other test groups before and after mechanical thermocycling loading (Table II, Fig. 2). During the measurement of tensile strength, the glass ceramic crowns fractured cohesively at all times (Fig. 3A). Aging did not significantly influence the results in the control group (Table III).

**DISCUSSION**

All tested cements showed no bonding when polymeric crowns were untreated. Pretreatment with alumina increased the results, except for VAR. This phenomenon can be explained by the fact that the both self-adhesive resin cements, GCM and RXU contained methacrylate monomers with acidic groups that eventually copolymerized with the industrially polymerized CAD/CAM resin. On the other hand, VAR is conventional resin cement based on Bis-GMA, TEGDMA, UDMA monomers that possible did not copolymerize with the CAD/CAM resin tested. The tensile strength of pretreated polymeric crowns cemented with all tested cements presented significantly lower values than those of the adhesively luted glass ceramic crowns. Therefore, the first part oft he null hypothesis of this study was rejected.

The glass ceramic crowns showed the highest tensile strength among all tested groups. In all specimens of this group, the glass ceramic crowns fractured cohesively. Consequently, the measured tensile strength of adhesion exceeded the cohesive strength of the ceramic itself. Therefore, this test method could not be adapted for glass ceramic crowns because of the lower flexural strength of the ceramic tested.[5] This phenomenon has also been observed with other test methods such as shear bond strength testing, where failure type is often cohesive in the glass ceramic.[11]

In this study, the second hypothesis tested the impact of air abrasion on the tensile strength of polymeric CAD/CAM crowns and nontreated ones. The air-abraded polymeric crowns presented higher tensile strength at all times, except for VAR. Therefore, the second part of the null hypothesis is also rejected. The reason for no adhesion with VAR, could be the lack of silane application. Since the study tested only the effect of micromechanical bonding, in these groups, no silane was applied. The adhesive failure type between the cement and the intaglio surfaces of all crowns showed clearly that the adhesion of these cements was higher to the dentin than to the crowns.

Air abrasion principally cleans and increases the surface area, resulting in higher bond strength due to mechanical retention.[6,7] Based on the results of this study, the adhesion between the polymeric crowns and the resin cements could be considered as mechanical retention. The polymeric blocks are industrially polymerized and present a high degree of conversion than manually polymerized ones.[22] Since the nontreated group showed no bonding, it can be stated that free radicals were not sufficient to achieve adhesion between the studied cements and the intaglio surfaces of the crowns. In this case, the use of conventional cement such as zinc phosphate could be an option. Regardless of the cements used, retention of the crowns is dominated by the parallelism of the preparation and the height of the crowns after preparation.

This study used the pull-off test with prepared human teeth, where polymeric CAD/CAM crowns were bonded according to standard clinical procedures. However, the teeth were prepared manually, and the water supply was not controlled with the handpiece as under clinical conditions. In a previous study, where the tensile strength of zirconia crowns cemented with self-adhesive resin cements on dentin were tested,[13] the results ranged between 7.3 MPa and 14.1 MPa. Although the identical experimental set-up was used, the results of this study indicated inferior adhesion of 2 of the cements (RXU, GCM) on the polymeric crowns.

The advantage of using pull-off-tests is the integration of the surface bonded area into the calculation. It can be assumed that the applied method presents a more precise calculation than previously published studies.[12,14,16,17] In 1 study, the bond area was measured by wrapping 0.1 mm tinfoil around the preparation to determine the weight of the foil.[12,14] In 2 other studies[16,17]the bond area of the specimens was calculated by using the formula for a truncated cone, to which the area of the flat occlusal surface was added. In the present study, the prepared abutments were scanned with a Cerec 3D camera and their areas were estimated with the Cerec 3 Volume Program.

In this study, thermomechanical cyclic loading aged the specimens, and the stress for all specimens was standardized and reproducible. In addition, this aging method corresponds to 5 years in vivo.[20] However, this assumption has not yet been systematically verified with different materials and is only based on the extrapolation of 4-year-clinical wear data on amalgam fillings and 6-months wear of composite resin inlays.[20] This correlation was only used for the wear rate tests. The clinical validity of the thermomechanical loading device for tensile strength tests is yet to be determined.

In summary, the crowns made from polymeric blocks showed significantly lower tensile strength than the glass ceramic crowns. In order to achieve adequate, long-term adhesion clinically, the bonding to such blocks must be further optimized. Further studies should also test other pretreatment methods for industrially polymerized resins such as silanization, silica coating, or application of methacrylate monomers.

## CONCLUSION

Within the limitations of this study, commercially polymerized resin CAD/CAM crowns presented significantly lower tensile strength than that of glass ceramic crowns. On the other hand, air abrasion increased the tensile strength of polymeric CAD/CAM crowns with the resin cements tested, except for VAR. All specimens with resin CAD/CAM crowns failed adhesively between the cements and the polymeric crowns.

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**TABLES**

Table I: Summary of products used.

| Framework, manufacturer | Cement, manufacturer | Composition of the bonding agents and cements | short name |
|---|---|---|---|
| Test groups | | | |
| PMMA resin artBloc Temp, Merz Dental, Lütjenburg, Germany, Lot.No 14408 | RelyX Unicem (Lot.No 361930), 3M ESPE, Seefeld, Germany | Powder: alkaline (basic) fillers, silanated fillers, peroxy components, pigments, substituted pyrimidine<br>Liquid: methacrylate monomers containing phosphoric acid groups, acetate, initiators, stabilizers | RXU |
| | G-Cem (Lot.No 0801091), GC Europe, Leuven, Belgium | Powder: fluoro-alumino-silicate glass, initiator, pigments<br>Liquid: 4-META, UDMA, dimethacrylate, water, phosphoric ester monomer, initiator, camphorquinone | GCM |
| | artCem GI (Lot.No 7806520)<br><br>artCem ONE (Lot.No 5811037) Merz Dental, Lütjenburg, Germany | Powder: barium-aluminum-silicate glass, nano-fluorapatite, pigments, initiator<br>Liquid: polyacid, methacrlylate , initiator<br>2-hydroxyethylmethacrylate, dimethacrylate, initiator, stabilizers | ACG |

| | | | |
|---|---|---|---|
| | Variolink II (Lot.No K41833/K39878)<br><br>Syntac Classic (Lot.No J280035/J27820), | Bis-GMA, TEGDMA, UDMA, benzoylperoxide, inorganic fillers, ytterbium trifluoride, Ba-Al fluorosilicate glass, spheroid mixed oxide, initiator, stabilizers, pigments<br>Primer: TEGDMA, maleic acid. dimethacrylate, water<br>adhesive: PEGDMA, maleic acid, glutaraldehyde, water | VAR |
| Control group | | | |
| Glass ceramic VITA Mark II, VITA Zahnfabrik, Bad Säckingen, Germany, Lot.No 18090 | Variolink II (Lot.No K41833/K39878)<br><br>Syntac Classic (Lot.No J280035/J27820),<br><br>Monobond S (Lot.No J17658)<br>Heliobond (Lot.No G09457) Ivoclar Vivadent, Schaan, Liechtenstein | Bis-GMA, TEGDMA, UDMA, benzoylperoxide, inorganic fillers, ytterbium trifluoride, Ba-Al fluorosilicate glass, spheroid mixed oxide, initiator, stabilizers, pigments<br>Primer: TEGDMA, maleic acid. dimethacrylate, water<br>adhesive: PEGDMA, maleic acid, glutaraldehyde, water<br>ethanol, water, silane<br>Bis-GMA, dimethacrylate, initiators, stabilizers | CONT |

Table II: Tensile strength values (MPa) with 95% confidence intervals and significant differences of all tested groups.

| Groups | Pretreatment | Aging | Mean (SD) | 95%CI | Failure types |
|---|---|---|---|---|---|
| RXU | No treatment | Initial | 0 (0) | - | all between polymeric crown and cement |
| | | Aging | 0 (0) | - | |
| | 50 µm $Al_2O_3$ | Initial | 2.2 (0.15) | (1.9,2.6)[b] | |
| | | Aging | 1.9 (0.20) | (1.4,2.4)[z] | |
| | 110 µm $Al_2O_3$ | Initial | 2.6 (0.28) | (1.9,3.3)[A] | |
| | | Aging | 2.0 (0.33) | (1.2,2.7)[Y] | |
| GCM | No treatment | Initial | 0 (0) | - | |
| | | Aging | 0 (0) | - | |
| | 50 µm $Al_2O_3$ | Initial | 1.4 (0.22) | (0.9,1.9)[a] | |
| | | Aging | 0.0 (0.0) | - | |
| | 110 µm $Al_2O_3$ | Initial | 2.8 (0.15) | (2.5,3.2)[A] | |
| | | Aging | 1.0 (0.20) | (0.5,1.5)[X] | |
| ACG | No treatment | Initial | 0 (0) | - | |
| | | Aging | 0 (0) | - | |
| | 50 µm $Al_2O_3$ | Initial | 2.1 (0.13) | (1.8,2.5)[b] | |
| | | Aging | 1.0 (0.19) | (0.5,1.5)[y] | |
| | 110 µm $Al_2O_3$ | Initial | 2.3 (0.15) | (2.0,2.7)[A] | |
| | | Aging | 1.2 (0.13) | (0.9,1.5)[X,Y] | |
| VAR | No treatment | Initial | 0 (0) | - | |
| | | Aging | 0 (0) | - | |
| | 50 µm $Al_2O_3$ | Initial | 0 (0) | - | |

| | | | | | |
|---|---|---|---|---|---|
| | | Aging | 0 (0) | - | |
| | 110 µm $Al_2O_3$ | Initial | 0 (0) | - | |
| | | Aging | 0 (0) | - | |
| CONT | etched | Initial | 7.3 (2.2) | (4.9;9.6) | all in the glass |
| | etched | Aging | 6.4 (0.9) | (5.4;7.5) | ceramic crown |

* Different superscripts represent a significant difference in each row, a,b between the initial groups sandblasted with 50 µm $Al_2O_3$ ($P<.001$); x,y,z between the aged groups sandblasted with 50 µm $Al_2O_3$ ($P=.002$); A between the initial groups sandblasted with 110 µm $Al_2O_3$ ($P=.236$) and X,Y,Z between the aged groups sandblasted with 110 µm $Al_2O_3$ ($P=.014$)

Table III: P-values of the 2 sample Student's t-test with mean difference and 95% confidence interval between initial and aging groups within 1 pretreatment and within each cement.

| Group | Pretreatment | P-value | Mean difference | 95% CI |
|---|---|---|---|---|
| RXU | No treatment | - | - | - |
| | 50µm $Al_2O_3$ | .231 | 0.31 | (-0.22;0.83) |
| | 100µm $Al_2O_3$ | .151 | 0.65 | (-0.26;1.55) |
| GCM | No treatment | - | - | - |
| | 50 µm $Al_2O_3$ | **<.001** | 1.37 | (0.89;1.85) |
| | 100 µm $Al_2O_3$ | **<.001** | 1.82 | (1.31;2.34) |
| ACG | No treatment | - | - | - |
| | 50 µm $Al_2O_3$ | **<.001** | 1.16 | (0.67;1.65) |
| | 100 µm $Al_2O_3$ | **<.001** | 1.15 | (0.72;1.57) |
| VAR | No treatment | - | - | - |
| | 50 µm $Al_2O_3$ | - | - | - |
| | 100 µm $Al_2O_3$ | - | - | - |
| CONT | etched | .416 | 0.83 | (-1.46;3.15) |

Table IV.: P-values of the 2 sample Student's t-test with mean difference and 95% confidence interval between with 50 µm $Al_2O_3$ and 100 µm $Al_2O_3$ airborne-particle- abraded groups, within aging or initial groups, and within each cement.

| **Group** | **Aging / No Aging** | **P-value** | **Mean difference** | **95% CI** |
|---|---|---|---|---|
| RXU | Initial | .230 | -0.39 | (-1.06,0.27) |
| | Aging | .932 | -0.03 | (-0.84,0.77) |
| GCM | Initial | **<.001** | -1.44 | (-1.99,-0.90) |
| | Aging | **<.001** | -0.99 | (-1.42,-0.55) |
| ACG | Initial | .378 | -0.18 | (-0.61,0.24) |
| | Aging | .421 | -0.19 | (-0.69,0.30) |
| VAR | Initial | - | - | - |
| | Aging | - | - | - |

**FIGURES**

Fig. 1. Design of tensile bond strength measurement.

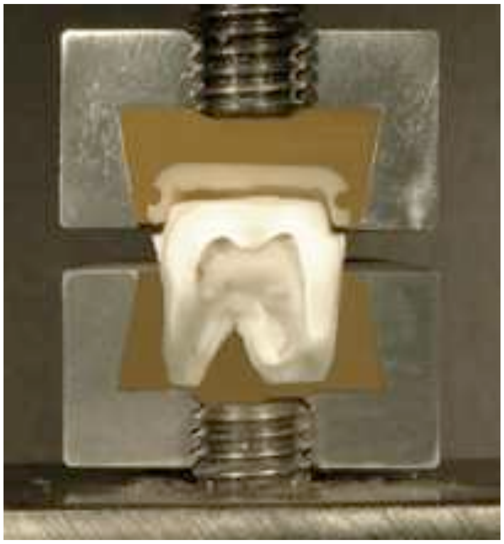


Fig. 2. Mean tensile strength results of all tested groups.

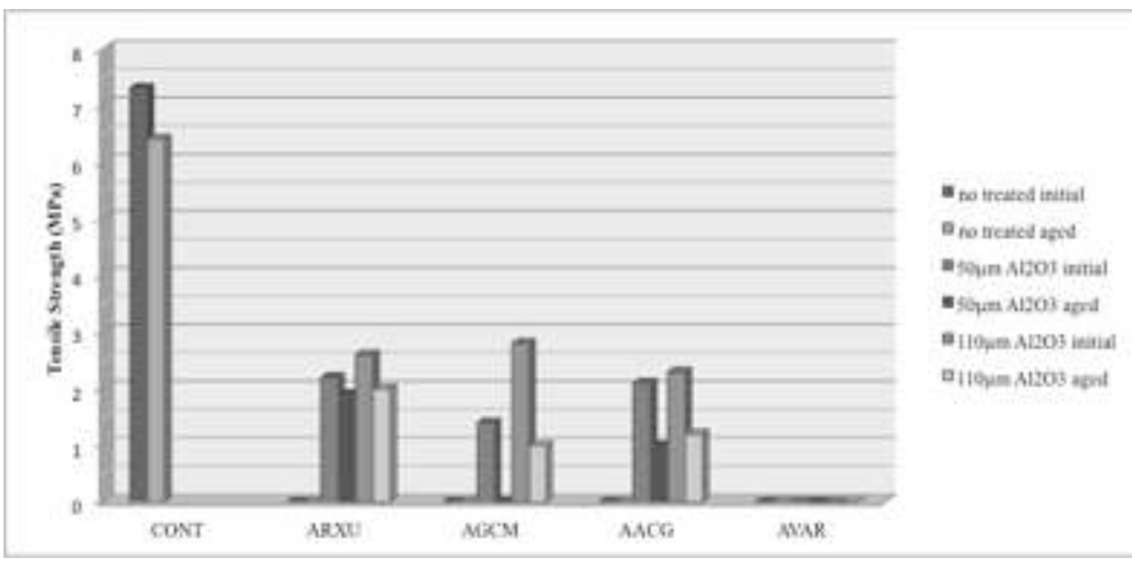
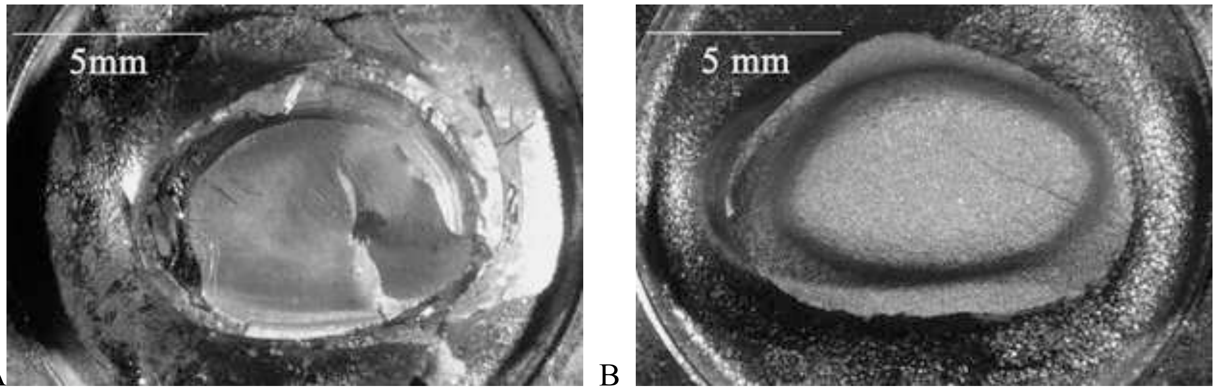


Fig. 3. Failure types after tensile strength measurements: A, fracture of glass ceramic crown. B, fracture in cement/ crown interface; note that all cement remained on abutment.




A B